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ORIGINAL PAPER

Over-mature beech trees (*Fagus orientalis* Lipsky) and close-to-nature forestry in northern Iran

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Abstract: Oriental Beech is the most important commercial tree species in northern Iran. In recent years wood production companies interested in felling large beech trees for profit have challenged advocates of close-to-nature silviculture who favor conservation. Our study objective was to assess the economic value of over-mature beech trees by relating tree diameter (DBH) to amount of decay. Based on the location of onset of decay, we categorized three types of decay as stump, stem, and crown decay. Trees of greater diameter (age) typically showed greater decay in the stem. Percent of decayed volume, diameter of decayed tissue, and length of decay in tree stems varied between 0.5%–64.3%, 15 cm–75 cm, and 2.0–19.5 m, respectively. With increasing trunk diameter, the proportion of truck decay increased. Red heart and dark red heart constituted 25% and 14.3% of sampled trees, respectively. However, we found no correlation between intensity of stem decay and morphological characteristics of trees. Seedlings were not abundant around the bases of over-mature trees, suggesting that the trees did not contribute to regeneration of the stand. Beech trees of diameter >1 m do not provide valuable round wood for industries and cause to raise wood production costs. We recommend that these trees >1 m DBH should be retained in forest stands because of their low commercial value but high ecological and conservational values such as maintaining biodiversity in forest ecosystems.

Keywords: Caspian forests; close-to-nature forestry; *Fagus orientalis*; red heart and stem decay; Iran

Introduction

The Hyrcanian region is located south of the Caspian Sea. In Iran this region covers approximately 50,000 km^2 in the provinces of Gilan, Mazandaran, and Golestan. Due to its humid, temperate climate, and fertile soil, this region is highly productive. Intensive human settlement of the lower elevations as early as AD 1100 left large portions of the lowlands deforested, after these areas were converted to agricultural, residential and industrial uses (Sefidi et al 2011). Oriental beech (*Fagus orientalis* Lipsky) is often a dominant species in the northern temperate forests of Iran. Beech forests in this region are mixed with *Carpinus betulus*, *Alnus subcurdate*, *Acer velutinum,* and other species. These forests are mostly broad leaved but *Taxus bacata* and *Cupressus* sp. appear on special sites (Marvie and Mohadjer 2005).

The concept of close-to-nature silviculture is an old one. It was developed by Karl Gayer at the end of the 19th century, and has been applied for more than one hundred years in Switzerland and Slowenia, mostly with success (Schüz 1996). Gayer’s 1886 book "Der Gemischte Wald seine Begrundug und Pflege" introduced concepts that remain fundamental to close-to-nature forestry. He advocated management systems based on small scale interference and group selection systems as the best methods for establishing and maintaining mixed forests (Leibundgut 1983; Otto 1993). The tree selection system was referred to by some foresters as the ideal of close-to-nature forestry, as it represents the ideal structure for permanent forest cover (Heyder 1986; Heilmann-Clausen and Christensen 2004; Marvie Mohadjer 2005). Forests in northern Iran are managed using to close-to-nature methods. Changing from a shelter wood method to a tree selection method introduces disagreement between wood production companies and advocates of close-to-nature

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forestry in northern Iran. Wood production companies selectively cut trees of large diameter to maximize profit, while advocates of close-to-nature silviculture believe that the ecological value of these trees exceeds their economic value and they should not, therefore, be felled. Our research attempts to show whether such trees have economic value adequate to justify their harvest.

Several types of biodegradation are recognized in timber, such as fungal decay, bacterial degradation, and insect attack. Fungal decay is the most important and widespread type of degradation as white-, brown-, and soft-rot (Zabell and Morrell 1992). White-rot fungi digest lignocelluloses and can break down lignin to carbon dioxide and water (Have and Teunissen 2001). Different models and techniques are used to monitor fungal decay such as spectroscopy of white-rot decay (Mohebby 2005), imaging (Hagrey 2007), enzymatic characterization (Lekounougou et al. 2008), ultrasonic detectors, thermography, radar, and X-ray tomography (Nicolotti and Miglietta 1998).

Nonliving heartwoods are vulnerable to decay, because they cannot respond actively to infection when exposed by wounds (Pearce 2000). Decay is a restriction in trees (Pearce 2000) and heart rot is the primary cause of decay in standing trees (Rayner and Boddy 1998). Heart rot degrades wood quality. It can take decades, even centuries, for a tree to complete the cycle of germination, maturation and decay. In standing trees, most wood decay fungi gain access through wounds on tree trunks and roots, from which they invade living hosts and cause decay.

Formation of red heartwood is an ecological phenomenon investigated by Knoke (2003) and others. Red heartwood is economically important because substantially higher prices can be derived from white beech logs if they are not infected with red heartwood (Seeling 1998; Knoke 2002). Richter (2001) reported annual losses due to red heartwood of €5.1 million for North Rhine-Westphalia. As for the European beech, red heartwood is a common disease in oriental beech.

In this study, we estimated the volume and intensity of decay in Oriental beech trees of DBH >1 m. We quantified the relationship between tree diameter and decay of beech trees. We assessed regeneration around the bases of large beech trees investigated the option of felling these trees to improve regeneration.

Materials and methods

Study site

We studied Oriental beech (*F. orientalis* Lipsky) stands located at 49°53'15" to 49°49'4" E and 36°58'16" to 36°55'10" N in Sistan forests, Gilan Province, northern Iran (Fig. 1). Oriental beech is one of the most common species growing in the northern temperate forests of Iran. These beech forests are mixed with hornbeam (*Carpinus bettulus*), Caucasian alder (*Alnus subcordata*), Maple (Acer velutinum) and other species, mostly broadleaved, and *Taxus bacata* and *Cupressus* sp. appear on special sites (Mohadjer 2005).

Fig. 1 Location of study sites in the Gilan province, northern Iran

The elevation of the study area ranged from 730 to 1,200 m a.s.l. Aspect was north and slopes ranged from 10% to 80%. The mean annual temperature is 13°C, and average of annual perception is more than 1 200 mm. Soil texture ranged from clay to clay loam.

Field measurements

Fifty-five over-mature beech trees (with diameter >1 m) were randomly selected for study after felling. Stem decay and colored heartwood were quantified for all trees based on the presence of decay and/or color of heartwood. We classified colored heartwood into two classes, red heartwood, the common colored heartwood, and dark-red heartwood, the advanced colored heartwood that is affected by bacteria or other diseases (Liu et al. 2005).

Morphological characters of beech trees were determined: e.g. spiral growth (trees with and without spiral grains), nodes (trees with and without visible nodes), bark color (light or dark bark), bark scars (presence or absence), crown break (trees with broken crowns and trees with intact crowns), and branch collar scars (presence or absence).

In order to measure the length and diameter of decay, we felled selected trees and cut their trunks into discs. We cut discs continuously along the length of the trunk even in sections with no sign of decay.

The shape of decay in beech trees was irregular, starting with a circle and tapering to a point at the end of the decay. We assumed the decay took the shape of a cone (Parson et al. 2003), so, we used a cone volume equation to calculate the decay volume:

$$V = \frac{1}{3}\pi r^2 h \tag{1}$$

where, V (m^3) is the volume of decay, r (cm) is diameter of decay, and h (m) is the length of decay. We also calculated the proportion of decay volume to whole tree volume. We calculated stocking volume according to a regional volume table.

For the investigation of decay and colored heartwood, we classified all sampled trees into three classes: (1) completely decayed trees with different decay patterns but not only red heart, (2) red heart trees, and (3) dark red heart trees.

We classified decay with respect to initial point of decay as follows:

Stump decay: decay started from stump (bottom of trees).

Stem decay: decay started in trunk.

Crown decay: decay occurred in tree crown (Moradi 2009).

To quantify regeneration around the bases of trees that showed signs of decay, we established circular sampling plots of 10 m radius (N-34) from the center of stump. In each plot, we counted and measured all seedlings and saplings, and assigned them to three diameter classes (<2.5 cm, 2.5–7.5 cm and 7.5–12.5 cm) and two height classes (<30 cm and 30–130 cm). Regeneration can be affected by multiple factors such as slope, land form, altitude, aspect and other parameters. To minimize variation due to these factors, we sampled plots of the same aspect (north facing slope) and in one compartment with the similar site conditions.

Data analysis

Our data did not conform to normality and other assumptions needed for parametric tests even after transformation. To investigate correlation between tree diameter and extent of decay (diameter and length), we used Spearman's rank test. We used the Bonferroni correction (Rice 1989) to adjust significance levels when the same data were used for multiple tests. We used Spearman correlation to relate morphological characters (spiral growth, nodes, trees bark scar and color, collar scar, and crown break) and stem decay.

Results

Different types of decay and colored-heart

Of 56 sampled trees, 34 (60.7%) showed decay. The remaining 22 trees (39.3%) were healthy but had colored heartwood (Table 1).

Stump decay was most prevalent, accounting for 67.6 % of decayed trees. Stem decay ranked second, accounting for 11.6 %. Stem decay was caused by holes, knots, or other parameters. Crown decay (8.8 % of sampled trees) was caused by broken crowns or other parameters. More than one of these types of decay was recorded for 12% of decayed trees (Fig. 2).

Table 1. Frequency of 56 sampled oriental beech trees according to decay pattern

Decayed Trees N = 34				Healthy Trees (Without Decay) N = 22	
Stump Decay N = 23	Stem Decay N = 4	Crown Decay N = 3	Other types N = 4	Red Heart N = 14	Dark Red Heart N = 8

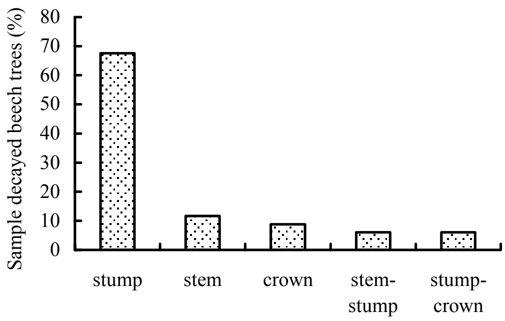

Fig. 2 Different types of decay in sampled over-mature beech trees

Decay diameter and length ranged between 15–75 cm and 2–19.5 m, respectively. Decay volume ranged from 0.06 m^3 to 11.48 m^3 per tree with 0.5%–64.3% of tree volume showing decay (Table 2). The maximum decay was 11.5 m^3. Decay typically occurred in the best woody part of trees, which is the most valuable timber for sale.

Table 2. Average and range of decay length, diameter and volume in 34 decayed trees. Decay volume proportion calculated by dividing decay volume to whole tree volume for oriental beech trees.

Parameter	Range	Mean
Decay length (m)	2–19.5	6.12± 4.06
Decay diameter (cm)	10–75	37.94± 18.05
Decay volume (m^3)	0.02–11.4	1.57± 2.56
Decay volume proportion (%)	0.47–64.2	10.26±14.08

Diameter at breast height was significantly correlated with diameter, length and volume of decay (Table 3). Also the majority of decayed trees (85%, N=29) showed up to 25% decayed part form the whole tree volume (Table 4).

Table 3. Correlation between decay dimension and tree diameter

	Decay length	Decay diameter	Tree diameter	Decay volume
Decay length	1	0.713**	0.669**	0.901**
Decay diameter	0.713**	1	0.673**	0.805**
Tree diameter	0.669**	0.673**	1	0.647**

**: Correlation is significant at the 0.01 level.

Table 4. Distribution of decay parameters according to decay per cent in over-mature beech trees according

Decay Classes (%)	Number of tree (N)	Minimum decay volume (m^3)	Maximum decay volume (m^3)	Average DBH (cm)	Average tree length (m)	Average stem length (m)
Up to 25	29	0.06	16.52	108	34.3	14.9
25.50	4	25.84	47.89	114	32.4	14
50-75	1	64.26	64.26	120	39	19

Tree diameter was not significantly correlated with red heart, but was significantly correlated with dark red heart (r = 0.208, p<0.05). Of morphological characters, only collar scar showed significant correlation with stem decay (r = 0.278 m, p<0.05; Table 5).

Table 5. Spearman correlation between decay and morphological characters in overmature beech trees

	Crown brokenness	Spiral growth	nodes	Skin scar	Collar rot	Skin color
Decay	0.122	0.156	0.162	0.213	0.278*	-0.042

*: Correlation is significant at the 0.05 level.

The greatest commercial value of trees is found in the lower trunk (Mohajer 1975). In this portion of sampled trees we recorded decay affected 10-100% of total trunk volume.

Regeneration

The total number of seedlings in first height class (<30 cm) and second height class (30–130 cm) around over matured beech trees in 100 m^2 were 980 and30, respectively. Number of seedlings in diameter classes <2.5 cm, 2.5–7.5 cm, and 7.5–12.5 cm were 106, 21, and 10, respectively. The dominant regeneration species was beech. This result was expected because all sampling plots were under beech canopies. Most seedlings of beech were in the shortest height class (<30 cm) and smallest diameter class 0–2.5 cm (Figs. 3 and 4).

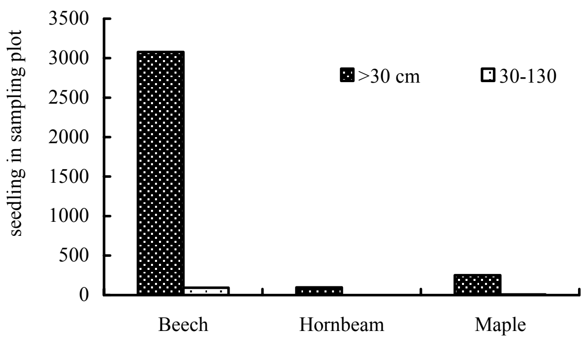

Fig. 3 Amount and species of seedlings by height classes (<30 cm and 30–130 cm height).

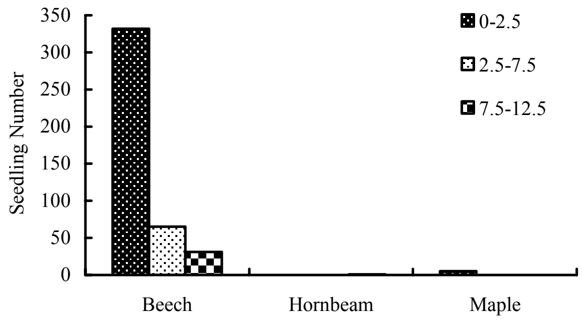

Fig 4. Number of seedling by different diameter classes (<2.5 cm, 2.5–7.5 cm and 7.5–12.5 cm)

Hornbeam (*Carpinus betulus*) seedling numbers ranked third among regenerating species. Most hornbeam seedlings, similar to beech seedlings, were ranked in the shortest height class and smallest diameter class. Hornbeam seedlings were nearly absent in in the upper classes, where only one seedling was recorded in the largest diameter class.

Although Maple (*Acer velutinum*) regeneration was more than of hornbeam, a similar pattern of decrease was recorded at taller height and larger diameter classes. Yew (*Taxus bacatta*) occurs naturally in oriental beech stands but we recorded only one seedling and it ranked in the shortest height and smallest diameter classes (Fig. 4). Yew is a rare species in our study area and it grows slowly but even in small numbers, the species is valuable.

The regeneration of dominant trees was poor, at 30 seedlings in 100 m^2 that was equal 0.3 seedlings per square meter.

Discussion

Decay and the associated deterioration and death of trees are a natural process in forest ecosystems and is partly responsible for the ever-changing nature of forests (Christensen et al. 2005). Although human activities tend to reduce numbers of large-diameter trees and volumes of standing dead timber, some well-managed forests retain a more natural balance of age and size classes. Saving such forests as management models is essential for extending the practice of close-to-nature forestry. Biodiversity is an important consideration in sustainable forest management and one characteristic of high-biodiversity forests is the volume of standing dead timber (Heilmann-Clausen and Christensen 2003). Standing dead trees provide habitats for wildlife (Pearce 2000; Lee 1998) but wood production companies typically harvest trees before they reach this condition. We recommend retention of trees of low timber value so they can decay and enhance overall forest biodiversity.

When tree diameters exceeded one meter, we found an increasing probability of decay. Tree diameter and tree age have an effect on decay in the trunk (Heilmann-Clausen and Christensen 2004). As tree age approaches the limit of life expectancy, the probability of decay increases (Hummel 2000; Knoke 2003) as does the volume of decay. We recorded significant timber volume loss in 0.5%–64.2% of sampled trees and these trees had

little high quality wood.

Beside trunk decay, 39.2% of studied trees had red or dark red heart. This is probably due to their advanced age. Knoke (2003) showed that tree age is one of the most important factors influencing the extent of red heartwood. Red heartwood can cause a decrease in wood quality and value. In our study area, such trees do not contain valuable round wood and are, therefore, often converted to fuel wood. This practice increases the cost of wood production per cubic meter and sharply raises forestry plan costs. Richter (2001) documented annual loss of €5.1 million in North Rhine-Westphalia due to red heartwood

Trees sampled in this study showed poor regeneration, most of which was confined to the area surrounding the base of the tree. Because of poor regeneration around over matured beech trees, cutting such tree can not improve regeneration in this area. According to main idea of regeneration, felling trees in shelter wood method often leave more space for seed trees to support forest regeneration. However, this fact can not be reliable in this area. We counted less than one seedling per square meters in our study.

Moreover, from the most number of regeneration observed in the first height class (<30 cm height), we can estimate the trees in the next developmental stages, and there wouldn't be enough regeneration for a next stand and falling such trees can not be useful in supporting new cohort. However, the predication of next stands and survival of seedling in forest can not be realistic, because climate change and other natural disturbance can affect the survival and growth of seedlings.

Beech is shade tolerant species and often established under canopy (Collet and Moguedec 2007; Forget 1992). Becch seedlings need at least need 3% of relative light for establishment (Szwagrzyk 2001, Parhizkar et al. 2011). Hence, we don't need to open canopy to support beech seedling. Other study results also showed that beech seedlings have better conditions for growth in close canopy and near the edge of the gaps (Dusan 2007). Other reports from virgin oriental beech stands showed regeneration of beec trees depend on single or double tree fall event that opened canopies in medium or in small size (Sefidi et al, 2011) that means removing over mature trees and opening canopy in large scale hav not role in stabilishmnet of beech as shad tolerant species.

Conclusion

We know that forests produce not only timber, but also many ecosystem services that can be more valuable than timber, such as oxygen production, carbon sequestration, landscape beautification, wildlife production, and water conservation. In other hand it should be noticed that there aren't lots of beech trees with more than one meter DBH in Caspian forests and even in other similar forests of the world, so from conservational point of view such trees have high value.

Our study showed that the portions of over-mature trees of highest potential timber value were decayed. Also, many of these trees had diseased that reduced wood quality. Over-mature trees did not contribute substantially to forest regeneration. Based on their poor regeneration and low wood quality, we recommended retention of over-mature trees. We conclude that it is better to retain these economically devalued trees to provide wildlife habitats and to enhance ecosystem health and balance. Over-mature trees can provide habitats for forest wildlife in future (Sefidi and Mohadjer 2010).

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